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ACKNOWLEDGMENT

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REST PAUSES IN MOTOR LEARNING AS RELATED TO SNODDY'S HYPOTHESIS OF MENTAL GROWTH

Chapter I

Nature of the Problem

The optimum length of practice and rest periods in learning has been an important problem to psychologists ever since the classical studies of Ebbinghaus (6) in which he found that distributed repetition of nonsense syllables gave significantly more efficient learning than concentrated practice. Subsequent studies by Jost (13), Book (2), Lyon (16), and others tended to confirm Ebbinghaus's general findings.

These studies were supplemented by research on the length of practice periods, intervals between trials, the stage of learning when rests were introduced, and the effect of the difficulty of the task to be learned. A bibliography covering these phases of the problem has been prepared by McGeoch (19).

The problem of spaced practice is concerned primarily with the *acquisition* of learning material, but the related problem of *retention* of what has been acquired has also been the object of experimental study. The type of analysis begun by Ebbinghaus has been made by many other experimenters, e.g., Luh (15), most of whom have obtained results similar to those of Ebbinghaus. These studies showed a rapid drop during the first hour following learning, which continued through eight hours at a slightly decreasing rate. After eight hours the rate of forgetting slowed markedly and indicated very little loss.

On the other hand, a number of studies have shown that the retention curve does not drop rapidly following learning, but continues to rise. This has been described as reminiscence by Ballard (1). Evidence of reminiscence has been found in the studies of retention of poetry by Ballard (1), by Williams (34), and by McGeoch (17). Ward (32) in a study on rote learning, showed that recall and relearning scores both indicated greater retention after a two-minute lapse of time than immediately following learning, and that the reminiscence effect reached its maximum at five minutes and then declined. Ward's results for rote learning have been verified by Hovland (8) and by Newman (21). The latter reports reminiscence even after forty-eight hours.

Theories which have been set forth to explain reminiscence are, for the most part, the same as those used to explain the general results of spaced practice. Fatigue, rehearsal, and perseveration are included by Hovland (8) in his summary of current theories of reminiscence. A recent theory has been developed by Hull and his associates (10) in their mathematico-deductive system based in part on the conditioned response. This theory postulates the existence of both excitatory and inhibitory processes in learning. It further assumes that the inhibitory processes weaken through the lapse of time at a more rapid rate than the excitatory tendencies. This would result after rest in an initial increase in effective excitatory strength. With a given amount of training, distributed practice should give relatively less accumulated inhibition. The theory would predict that there should be less reminiscence in distributed practice because the inhibitory process would have largely disappeared during the previous rest period.

This theory is favored by both Ward (32) and Hovland (8), the latter having recently produced experimental data confirming the aspect of the theory which predicted more reminiscence following massed than following distributed practice.

In a recent attack upon the problem of spaced practice Snoddy (28) has brought forth a new theory based upon an extensive study of mirror vision coordination. The time intervals between practices of the various groups ranged from continuous practice to rest periods of 24 hours. From his analysis of the data Snoddy concluded that there are two opposed processes of mental growth, primary growth and secondary growth. He describes these as follows: "Primary growth comes early and is enhanced by interpolated time; it approaches its maximum as the length of the interpolated time is increased. Secondary growth comes later and is enhanced by reducing the interpolated time; it is maximum when the interpolated time is zero, or when the practice may be said to be continuous" (28, p. 15). Primary learning is stable and resists loss; secondary learning is unstable and is lost over a long time interval.

Snoddy places strong emphasis upon the part which time plays in mental growth. He writes: "Primary growth is a positive function of the length of interpolated time. One may ask if this greater gain for the time-interval group must increase indefinitely as the length of the interval is increased; and the answer most certainly will be in the affirmative. There is no known reason why any growth which is proven to be a function of time should ever cease" (28, p. 20).

It is apparent that Snoddy's experiments and his interpretation have important bearing upon the problem of spaced practice and also upon the concept of reminiscence.

A number of studies on the time factor in motor learning have been the outgrowth of Snoddy's work. Humphreys (12), a student of Snoddy, has tested the Snoddy hypothesis by means of the Koerth pursuit rotor,[1] involving eye-hand coordination. Humphreys believes that his results agree with Snoddy's in showing greater gains in the early stages of learning *between* practice periods, while in the later part of learning the gains are made *during* practice periods.

Travis (30) also used the pursuit rotor and studied the effect of 6-minute work periods separated by intervals of 3 and 7 days and found that gains between practice periods were evident and that they were confined largely to the early stages of learning, a finding which agrees with Snoddy's conception of primary growth.

In a second experiment Travis (31) used a pursuit-oscillator, a test of motor coordination somewhat similar to the pursuit rotor, but which differs from the rotor in that the pattern of movement to be followed by the subject changes in speed, while the pattern of the rotor remains constant. He studied the effect upon the rate of learning, of rest periods varying in length from 5 minutes to 120 hours. Travis found that the rest period of 20 minutes was more effective than rest intervals of 5 minutes, 48 hours, 72 hours, and 120 hours, and that the rest period of 5 minutes was better than the three longest periods. The differences in

[1] For a description of this apparatus see page 6 of this study.

effectiveness of the three longest periods was insignificant. Since there was a most favorable rest interval, the results are in disagreement with Snoddy's prediction that the longer the interval the greater the gain.

Renshaw and Schwarzbek (22) have also studied the effect of the length of time for rest periods upon the learning of a motor skill. They used the pursuit meter which is similar to the Koerth pursuit rotor in that the subject has to learn to follow a small target. However, the pattern of the target on the pursuit meter differs from that of the pursuit rotor in that it is continually changing in direction and rate, while for the pursuit rotor the direction and rate remain the same. The rest intervals in their experiment were spaced differently for each of four groups of subjects. The first group was in a progressively decreasing order; the second, in a progressively increasing order; the third, in a progressively decreasing-increasing order; and the fourth, in a progressively increasing-decreasing order. From this study the authors conclude that a progressively decreasing rest period favors more rapid and effective improvement than do progressively increasing rests. This conclusion agrees with Snoddy's hypothesis that time is more effective in producing gain early in learning than it is late in learning. However, Doré and Hilgard (5) have replotted Renshaw and Schwarzbek's data in terms of elapsed time instead of by trials and they report that this change indicates that the data in fact favor increasing rests, contradicting Snoddy.

Doré and Hilgard (4) studied the effects of differential spacing of rest periods in pursuit-rotor learning where subjects, in group designated A, B, C, and D, practiced on the rotor for various amounts of time within one 43-minute period. Three of the groups, A, B, and C, practiced for 1-minute periods and rested 11, 3, and 1 minutes respectively between trials. Within an equal number of trials Group A made the largest gain, Group B next, and Group C third in order. Group D practiced 3 minutes and rested 1 minute and had the same number of practice trials as Groups A, B, and C. The performance of Group D, within an equal number of trials, was the poorest of the 4 groups. When the scores for Groups A, B, and C, were plotted by time elapsing from the beginning of practice, instead of by trials, the performance curves were not markedly different. When all the groups were practiced in a final trial with fatigue effects approximately equal, the scores tended to fall in order of the amount of practice. Thus the authors conclude that growth in pursuit learning may take place *during* rather than *between* trials, which is contrary to Snoddy's view.

Following this study, Doré and Hilgard (5) made a more direct test of Snoddy's hypothesis. From Snoddy's statement that primary growth comes early in learning and is facilitated by interpolated time and that secondary growth comes late in learning and is enhanced by reducing the interpolated time they derived the theorem that "if two equated groups of subjects are given the same number of practice trials distributed over the same total time, but the practice is differently distributed, that group which is given initial spaced practice and final massed practice should show higher scores at the end of the period than the group which is given initial massed practice and later spaced practice."

Again using the pursuit rotor, they tested this theorem in an experiment in which the number of trials and the amount of time were equal for two groups of subjects, but for one group the trials were first massed and later spaced, while for the other group the trials were first spaced and later massed.

The results of the experiment showed that the group for which the trials were massed at the beginning and later distributed made final scores significantly higher than the group for which the trials were distributed at the beginning and massed toward the end. These results, of course, are directly the opposite of what would be predicted from Snoddy's hypothesis.

Because their data do not support Snoddy's hypothesis, Doré and Hilgard (5) suggest a scheme of classification within which the evidence on motor learning may be discussed. Their classification includes two sets of factors: learning factors and work factors. Learning factors include improvement within practice, or acquisition, and loss with non-practice, or forgetting. Work factors include loss within practice, or work decrement, and improvement with non-practice or recovery with rest. They contend that Snoddy's postulation of primary growth to account for the unfavorable effects of massing and the advantages of spacing is unnecessary and that the growth between trials can be accounted for in terms of work decrement and recovery. With respect to secondary growth, they hold that this aspect of learning is more effectively described as forgetting.

In Snoddy's (26) reply to Doré and Hilgard's experimental test of his theory, he points out that their method is "artificial" and not capable of testing his theory. He states that they have made time a constant in their study while in his own experiments, time was a variable throughout. He also states that an "interference" factor was present in Doré and Hilgard's group which was given spaced practice early and massed practice late because the subjects in this group had become adapted to time-interval conditions in the same practice sittings. He shows from his own experiments that this interference factor arises whenever subjects who have become adapted to spaced practice during one sitting are later shifted to a condition of continuous practice. He predicts that if Doré and Hilgard had removed the interference factor by interpolating an overnight rest they would have found the two groups at the same efficiency level. This contention has not been subjected to test.

PROBLEM OF PRESENT INVESTIGATION

A review of the studies on distributed and massed practice as a whole, and those experiments in particular which are related to Snoddy's hypothesis of primary and secondary growth, indicates that there is need for a crucial test of Snoddy's hypothesis. As has been stated, Snoddy holds that primary growth occurs early in learning and is facilitated by the increase of time between trials while secondary growth occurs later in learning and is enhanced by the reduction of time between trials. The problem of the present investigation is to test experimentally the validity of this hypothesis by introducing differential rest periods at two points in the learning process, one early in learning when rises following rests are to be expected, and one late in learning when losses following rests may be expected. The arrangements of the experiment permit a test not only of the general direction of changes over the interspersed early or late rest periods, but also the modification in these changes with longer and shorter rests. If as rest intervals early in learning become longer gains become greater—and if as rest intervals late in learning become longer gains become less—then the study will agree with the predictions of the Snoddy hypothesis. If such changes are not obtained, the hypothesis must be rejected. If the changes are obtained, the hypothesis remains plausible, but must still be judged in the light of equally plausible alternatives.

Chapter II

Procedure and Method

APPARATUS

The apparatus used in the present experiment was the Koerth (14) pursuit rotor, a unit of the Stanford motor skills tests (25). The rotor consists of a small circular target of brass, 1.9 cm. in diameter, mounted on an insulating disc which rests upon a phonograph turntable. The subject attempts to hold a stylus on the target as the disc turns at the rate of one revolution per second. The stylus is hinged to permit the brass pointer to move freely in a vertical plane while the subject holds the wooden handle. A commutator of ten brass plates sunk in the edge of the disc in such a way as to present a smooth surface of alternating metal and bakelite permitted ten electrical contacts during each revolution of the disc. The impulses were recorded by an electromagnetic counter. A score of ten for each revolution of the disc is maximum and any failure to keep the stylus on the target results in a lower score. Throughout the experiment scores were reported for trials of one-minute duration, or 60 revolutions of the disc, the maximum score being 600.

SUBJECTS

Results were reported for 11 groups of subjects, 10 experimental and 1 control. The control group contained 40 subjects and the experimental groups had from 40 to 46 subjects in each group, making a total of 457. Four hundred thirty-six were undergraduate students at Chico State College in California and the remaining 21 were from the Yuba County Junior College at Marysville, California. The subjects in each group were composed of approximately equal numbers of the two sexes.

EXPERIMENTAL PROCEDURE

All subjects were treated alike with respect to preliminary instructions in the use of the stylus and in a demonstration of the pursuit rotor. The tests were given in a room free from distraction and in which there was good light at all times. Each subject was tested individually. All subjects completed twenty 1-minute trials on the rotor, with the trials separated by 1-minute rest periods except for a single longer rest. Longer rest periods were introduced as follows: Group B was given a 10-minute rest following the 5th trial; Group C, a 1-hour rest following the 5th trial; Group D, a 6-hour rest following the 5th trial; Group E, a 24-hour rest following the 5th trial; and Group F, a 30-hour rest following the 5th trial. Thus groups B to F, all with rests after the 5th trial, constitute the groups with *early* rests. Group G was given a 10-minute rest following the 15th trial; Group H, a 1-hour rest following the 15th trial; Group I, a 6-hour rest following the 15th trial; Group J, a 24-hour rest following the 15th trial; and Group K, a 30-hour rest following the 15th trial. These groups, G to K, constitue the groups with *late* rests. The control group, Group A, received only the 1-minute rest periods between all their trials.

During the 1-minute and the 10-minute rest periods the subjects were seated and given a popular magazine to read. For the longer rest periods the subjects left the laboratory and did not return until just before their rest intervals had expired. The motivation of the subjects was good, nearly all of them expressing interest in the experiment and asking many questions about it. About one-third of the subjects were volunteers who had been told about the experiment by friends who had already taken it.

MATCHING THE GROUPS

The 11 groups of subjects practiced alike for the first 5 trials, so that it was possible to determine how well they were matched in ability upon the basis of their performance on trials 1 through 5. To obtain 11 groups equal in ability it was necessary to reassign arbitrarily some subjects to different groups after their first trial, and to drop entirely a few others. This procedure is justified since there were no experimental conditions introduced until after the 5th trial. The number of re-assignments were 5 for Group G, 5 for Group C, and 3 for Group J.

Of the total of 488 subjects who participated in the study there were 31 eliminated either because they made little or no progress in learning the rotor, as, for example, one subject who began with a zero score and ended with a score of 19 at the 20th trial; or because their initial scores were too high to be included in the group for which they were scheduled and they could not be reassigned to other groups because the new time for the test conflicted with their school classes or with the time which had already been scheduled for other subjects.

The means and standard errors of the means for the 10 experimental groups and for the control group on trials 1 and 5 are summarized in Table 1. From this table it is evident that the 11 groups of subjects were well matched in ability on the pursuit rotor. The greatest difference between any of the groups on the first trial is that of Groups G and I. The difference in this instance is 17.8, and its standard error is 10.2, yielding a critical ratio of 1.7, well within the limits of the

TABLE 1

Means and standard errors of the means for trials 1 and 5 for the eleven groups of subjects on the pursuit rotor. All groups treated alike within these trials.

Groups	Trial 1		Trial 5	
	Mean	σ_M	Mean	σ_M
A. *Control* (1 minute intervals throughout)	51.4	8.6	215.0	18.2
Groups with longer rests to be introduced after trial 5				
B. (10-minute rests)	63.0	10.1	221.6	17.6
C. (1-hour rests)	60.5	8.2	219.1	16.7
D. (6-hour rests)	55.1	8.2	220.1	14.8
E. (24-hour rests)	56.0	8.4	210.9	12.6
F. (30-hour rests)	61.7	7.6	220.3	16.0
Groups with longer rests to be introduced after trial 15				
G. (10-minute rests)	46.0	5.9	217.0	17.9
H. (1-hour rests)	55.4	6.2	221.4	15.7
I. (6-hour rests)	63.8	9.1	216.1	15.1
J. (24-hour rests)	56.2	7.1	223.2	16.5
K. (30-hour rests)	61.2	9.3	217.0	17.6

chance sampling error. This is verified by the fact that the averages for these two groups are practically equal at the 5th trial. The largest difference among the averages of the 11 groups at the 5th trial is between Groups E and J. This difference of 12.3 has a standard error of 20.76, yielding a critical ratio of 0.6, indicating that these groups were satisfactorily matched.

Chapter III

The Course of Learning

THE COMBINED CONTROL GROUP

The control group, Group A, was designed to provide a typical performance curve for 20 trials on the pursuit rotor when the trials were uniformly spaced at a rest interval of 1 minute. The changes introduced by the longer rest intervals early and late in practice could then be compared with this reference curve. The obtained learning curve is plotted as a broken line in Figure 1.

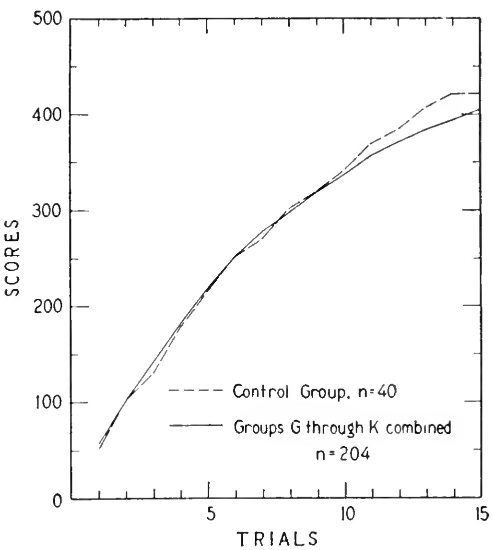

Fig. 1. Control group compared with Groups G through K combined.

Each point is a mean of the scores of the 40 subjects in the control group.

To determine how representative the control group was of the other data obtained at trials spaced at 1-minute intervals, scores for Groups G to K were averaged for each trial up to trial 15, after which a longer rest was introduced. The first 15 trials of these groups should correspond to the first 15 of the control group since no experimental variation was introduced. The solid line of Figure 1 gives these values, the means from 204 subjects. The two curves agree substantially for the first 10 trials, and then they diverge. At trial 15 the difference is 17.5 points. While such a difference is easily accounted for by chance, since the critical ratio is only 1.15, it would appear plausible to expect the 'true' value to be

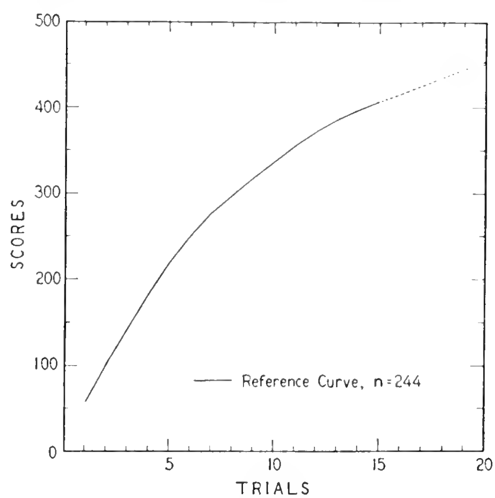

Fig. 2. The reference curve.

nearer the mean of the whole measured population.

In order to secure the most stable and representative curve with which to compare the separate groups, the scores of trials 1-15 inclusive for Group A were combined with the same trial scores for Groups G, H, I, J, and K. This curve was then extrapolated for trials 16 to 20.[2]

[2] The combined curve was found to be approximately logarithmic between trials 6 and 15, so that the extrapolation could be made mathematically according to the equation $Y = 388 \log_{10}$

The curve with the extrapolation is shown in Figure 2 by the solid line to trial 15 and the dotted line from trial 15 through trial 20. In this chapter, for purposes of general comparison this derived curve will be used as the reference curve for the combined control group, since this is the best prediction of the curves of Group B, which had a 10-minute rest following the 5th trial, and Group C, with a 1-hour rest after the 5th trial, are presented in Figure 3, where they may be compared with the reference curve for the combind control group.

It is clear that these groups were well matched between trials 1 and 5, where

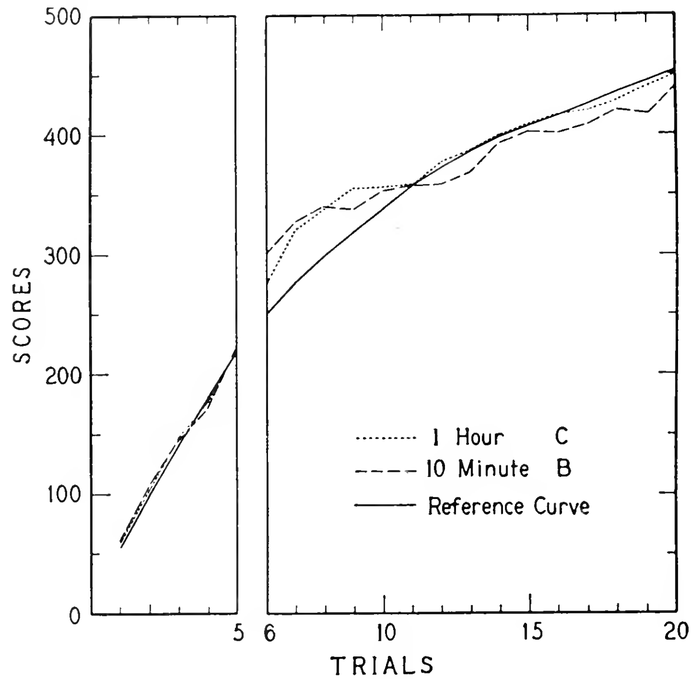

FIG. 3. Short rest pauses interpolated early in learning.

course of learning if no rest period is introduced.

EFFECTS OF EARLY REST PERIODS FOLLOWING THE 5TH TRIAL

In order to demonstrate the changes in the course of performance following a longer interspersed rest, learning curves will be presented first for rests after the 5th trial, and then for the later rests, after the 15th trial. The performance all experimental conditions were the same. At trial 6, Group B shows a rapid gain up to the 9th trial, at which point it begins to slow up and by the 12th trial it has fallen below the reference curve.[3] It takes another spurt at trials 13, 14, and 15, but never again rises above the reference curve, and ends at trial 20 somewhat below it.

Group C, with a 1-hour rest following

X − 51, where Y = score and X = trial number. Empirical values are used in trials 1 to 15, extrapolated values beyond.

[3] In this chapter, gross changes will be described. The statistical significances of quantitative differences will be presented in later chapters.

the 5th trial, shows a gain at trial 6 somewhat under that of Group B but above the reference curve. Group C makes a more rapid gain from trials 6 to 7 than Group B, suggesting the possibility of a "warming-up" effect, a point which will be dealt with more extensively in Chapter IV. Group C continues to gain up to trial 9, but at trials 10 and 11 gains practically nothing, and at trial 11 approaches the reference curve. From trials 12 to 15 Group C rises slightly higher than the reference curve, but drops at trial 16 and intersects it, ending below it at trial 20.

The learning curves of Group D, which had a 6-hour rest, Group E, a 24-hour rest, and Group F, a 30-hour rest—all rests after the 5th trial—are shown in Figure 4. The reference curve is also plotted.

As shown in this figure, all of these groups were well matched in ability from trials 1 to 5. At the 6th trial, following a 6-hour rest, Group D showed a marked gain and continued to gain rapidly from trials 6 to 7. After trial 7, it slowed up somewhat but still remained well above the reference curve throughout the balance of the trials, ending at trial 20 above all other groups.

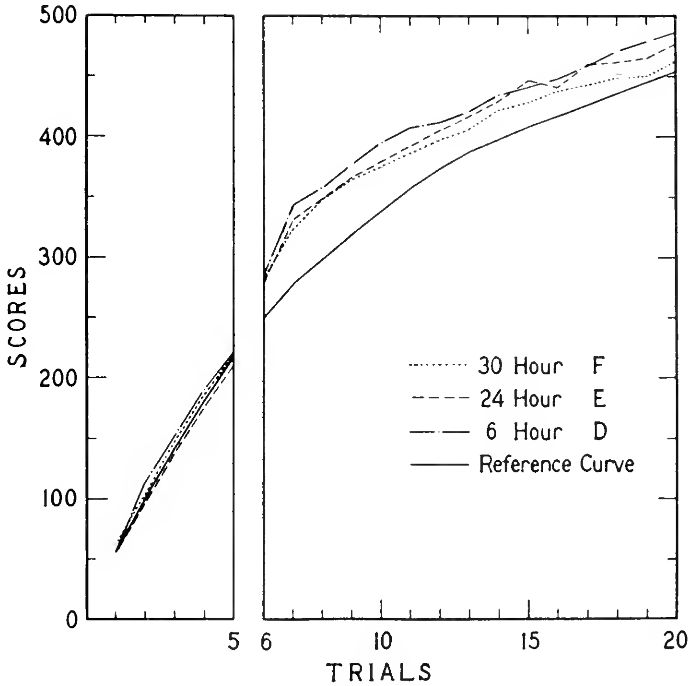

Fig. 4. Longer rest pauses interpolated early in learning.

Groups E and F also showed rapid improvement after their respective rests of 24 and 30 hours and continued well above the reference curve up to trial 12, where Group F began to drop off. By trial 19 it had lost most of its advantages over the reference curve and ends just slightly above it. Group E showed some irregularity in gains after trial 15 and ends at trial 20 above the reference curve and Group F, but somewhat below Group D.

The similarities between the curves for

Groups D, E, and F are more striking than their differences. These longer rest periods placed early in learning seem to affect learning progress on the pursuit rotor favorably and to much the same extent regardless of whether they are 6 hours, 24 hours, or 30 hours in length.

When Figure 4 is compared with Figure 3 it appears that the initial gains following the rest periods are maintained better in the later stages of learning for the longer rest intervals than they are for the shorter rest intervals.

Since the groups with the longer rest periods attained somewhat higher final scores than the groups with shorter rest periods the data so far seem to agree with Snoddy's hypothesis that early rests should be favorable, and the longer the better. However, final judgment on this point cannot be made until a more analytical study of the data is presented.

EFFECTS OF LATE REST PERIODS FOLLOWING THE 15TH TRIAL

The learning curves for Group G, which had a 10-minute rest following the 15th trial, Group H, with a 1-hour rest after the 15th trial, and the reference curve are presented in Figure 5.

These three groups appear to be well matched, as they start with average scores which do not differ to a significant degree, and continue to improve through trial 15 at the same rate. After the rest of 10 minutes Group G showed a definite gain and was well above the level of the reference curve at trial 16. It continued to gain through trials 17, 18, and 19, and reached trial 20 still above the reference curve. It is to be recalled that the reference curve represents the expected course of improvement with a 1-minute rest. A 10-minute rest late in learning has therefore brought more gain than a

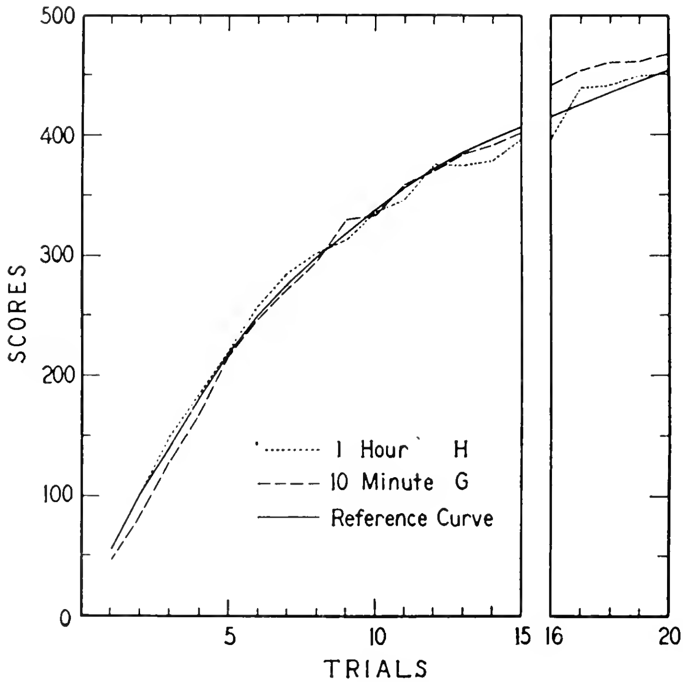

FIG. 5. Short rest pauses interpolated late in learning.

1-minute rest, disagreeing with the Snoddy hypothesis.

Group H, with a 1-hour rest after the 15th trial, made practically no gain at trial 16 and fell considerably below the level of the reference curve at that point. However, from trial 16 to 17, Group H showed a rapid gain and rose above the reference curve, holding an advantage over it through trial 19. At trial 20 it again lost and ended near, but below it. The rapid gain at trial 17 suggests that the relatively poor performance of Group H on trial 16 may have been due to the need for a "warming-up" trial.

The effect of longer rest periods placed late in learning is shown in Figure 6. Learning curves for Group I, with a 6-hour rest, Group J, a 24-hour rest, and Group K, a 30-hour rest—all rests after the 15th trial—are presented with the reference curve.

These groups are fairly well matched to the 15th trial, although Group J, from the 8th trial showed slightly more improvement than the other groups.

Following a rest period of 6 hours after trial 15, Group I showed a definite loss and dropped markedly below the level of the reference curve. Group J, with a 24-hour rest, also showed a loss at trial 16 and dropped considerably below the reference curve in spite of the fact that it was above it at trial 15. Group K, with a 30-hour rest, likewise, showed a distinct loss at the 16th trial, but did not drop so low as Group I. These consistent losses for all intervals beyond 1 hour agree with Snoddy's contention that a late rest should be deleterious.

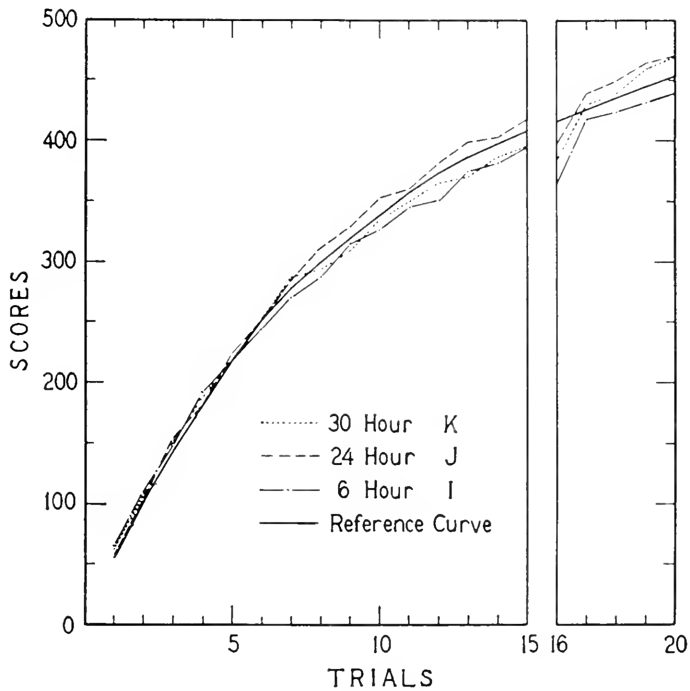

FIG. 6. Longer rest pauses interpolated late in learning.

At the 17th trial the three groups, I, J, and K, all showed rapid recovery and regained their former positions relative to the reference curve. From trials 17 to

TABLE 2

Combined means at the 5th and final trials of all early and all late rest groups, and the mean change at rests

Rest Periods	5th trial Mean	5th trial σ_M	Change at rests Mean	Change at rests σ_M	Final trial Mean	Final trial σ_M
All Early (N = 213)	218.2	6.9	66.8	3.7	464.3	5.1
All Late (N = 204)	218.8	7.4	−2.5	4.4	459.6	4.9
Difference	.6		69.3		4.7	
σ_D	10.4		5.8		7.1	
Critical Ratio	.06		*11.95*		.66	

20 Group I continued to gain and its final trial was only slightly lower than the reference curve, while Groups J and K completed trial 20 at a level slightly above that of the reference curve. From these data it appears that the need for warming-up may have been in part responsible for the losses shown following the longer rest periods, but this may also be interpreted as a rapid relearning following forgetting.

Our results show that the shorter rest periods late in learning produce gains, while the longer rest periods tend to produce losses. This, on the surface, appears to support Snoddy's hypothesis, since he predicts that growth late in learning is facilitated by the reduction of rest time. However, Snoddy's theory does not explain why the 10-minute rest group gained so much more than the 1-minute rest group, (i.e., the control group) following the 15th trial. It appears that this greater gain for the 10-minute rest may be similar to the "reminiscence" effect as found by Ward (32) and other investigators.

STATUS AT END OF 20 TRIALS

Since all our groups were given the same number of trials and differ only in the way in which the trials were distributed it is possible to compare all subjects who rested early in learning with those who rested late in learning, the mean total time being alike for the two groups. This gives groups of 213 subjects for early rests and 204 for late rests. The comparison of these groups is shown in Table 2.

The difference between the means at the 5th trial for the two groups is .6 and the standard error of the difference is 10.4, yielding a critical ration of .06. From this it is clear that the two groups were equal in ability at the 5th trial.

The early rest group showed an average gain of 66.8. This is compared with the expected gain of 33 points obtained with the combined control group which rested 1 minute after trial 5. The late rest group showed an average loss of 2.5 compared with an expected gain of 11 points by extrapolation of the reference curve. The gross difference between the mean changes at rests for the early and the late groups is 69.3 with a standard error of the difference of 5.8 and a critical ratio of 11.95. When adjustment is made for expected gains the net difference between the early and late rest groups is 47.3. These data appear to confirm Snoddy's view that interpolated time enhances growth when placed early in learning and has a depressing effect when placed late in learning.

However, at the final trial the average for the group with early rests is 464.3 and for the late rest group, 459.6. The difference between the averages is 4.7 and the standard error is 7.1, yielding a critical ratio of .66. Since Snoddy contends that primary growth is stable these gains which were found when the rests were placed early should be retained and yield average scores on the final trials significantly higher than where the rest periods were placed late in learning. That this was not found to be true means that Snoddy's theory is of limited applicability and needs supplementation, even if certain aspects of it are confirmed.

In order to provide a more rigorous test of Snoddy's hypothesis, and if possible to provide a more meaningful interpretation of the findings of this investigation, a more detailed analysis of retention at trials 6 and 16 and trials 7 and 17 was made.

Chapter IV

Retention Following Rests

In the previous section of the study the general progress of learning for all the groups in the present investigation was presented. In this section a more detailed analysis is to be made of the effect of differential rest periods upon retention of the 6th and the 16th and at the 7th and the 17th trials. Figures 7 and 8 show the effects on retention of introducing rest periods of the same durations early and late in learning. In Figure 7 the scores on the ordinate represent differences between the means of Groups A, B, C, D, E, and F at trials 5 and 6, and in Figure 8, of Groups A, G, H, I, J, and K at trials 15 and 16. The rest intervals are represented on the abscissa. The data are plotted like conventional retention curves.

The curves for both the early and late rest groups show a rapid rise for the shorter rest intervals of 1 minute and 10 minutes, the rise being greater for the early rest than for the late rest group. A drop occurs in both curves at the 1-hour rest periods. At the 6-hour rest intervals the two curves are markedly different, the early rest group showing a rise, while the late rest group shows a drop to the point of an actual loss. At the 24-hour and 30-hour rest intervals the two curves maintain about the same level as at the 6-hour intervals, with the late rest group showing a tendency to lose somewhat less than at the 6-hour rest.

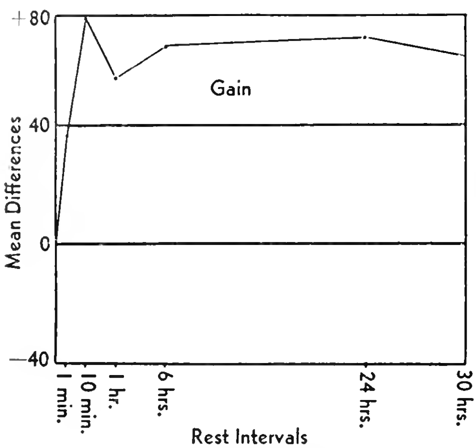

Fig. 7. Retention over rests after the 5th trial.

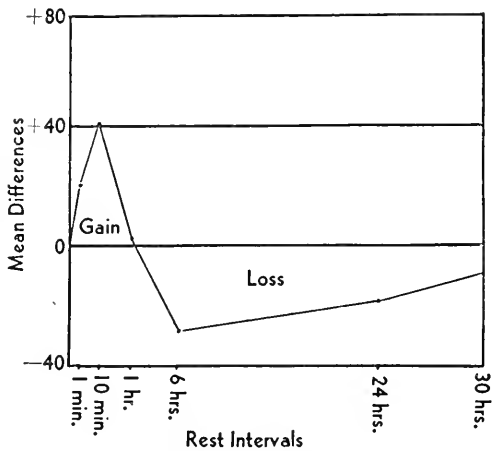

Fig. 8. Retention over rests after the 15th trial.

RETENTION AT TRIAL 6, FOLLOWING EARLY RESTS

The means of Groups A, B, C, D, E, and F at trial 6, their differences, and standard errors of the differences are given in Table 3.[4]

Group A, the control group, which rested 1 minute at the end of trial 5,

[4] The critical ratios comparing each group with all other groups have been computed and are in the dissertation on file in the Stanford University Library.

TABLE 3

Retention measured by changes over early rest intervals at trials 5–6

Rest Interval	Mean at Trial 5	Mean at Trial 6	Mean Change	σ_M
1 minute (A)	215.0	251.0	36.0 gain	7.0
10 minutes (B)	221.6	300.3	78.7 gain	7.0
1 hour (C)	219.1	274.1	55.0 gain	8.1
6 hours (D)	220.1	286.3	66.2 gain	8.0
24 hours (E)	210.9	281.5	70.6 gain	9.0
30 hours (F)	220.3	282.8	62.5 gain	8.5

made an average gain of 36 points at trial 6, while Group B, which rested 10 minutes, gained 78.7 points at trial 6. The difference between the gains of 42.7, with a critical ratio of 4.31, reflects a reliable difference between rests of 1 minute and 10 minutes when placed at the 5th trial.

When Group A is compared with Group C, which had a 1-hour rest, Group D, a 6-hour rest, Group E, a 24-hour rest, and Group F, a 30-hour rest, it is clear that the longer rests, with the exception of Group C, all yield scores which are significantly higher than that for Group A. Group C, with the 1-hour rest, gained only 19 points more than Group A, yielding a critical ration of 1.78.

When Group B, with the 10-minute rest, is compared with the other groups with longer rest periods the only difference which approaches significance is that between Group B and Group C, in which case the critical ratio is 2.22.

There were likewise no significant differences in the gains when Group C was compared with Groups D, E, and F, when Group D was compared with Groups E and F, nor when Group E was compared with Group F.

From these data, one may conclude that a 10-minute rest interval placed early in learning tends to give significantly better retention than a 1-minute rest, but that the introduction of longer rest periods, up to 30 hours, does not bring about significant improvement in retention.

This finding obviously is contrary to the Snoddy hypothesis which predicts that the increase of time early in learning brings about a corresponding increase in primary growth. If Snoddy is right, some additional factor must be operative. The superiority of the 10-minute rest group over the 1-minute rest group appears to be related to the findings of Ward (32) on reminiscence. This will be given more detailed treatment in Chapter VI.

RETENTION AT TRIAL 16, FOLLOWING LATE RESTS

The means of Groups A, G, H, I, J, and K at trial 16, their differences, and standard errors of the differences are given in Table 4.

Group G, which rested 10 minutes, showed a gain of 41.4, while Group A, the control group, gained 19.8 at trial 16. This difference of 21.6 is 2.22 times the size of its standard error, indicating that a difference of this magnitude would occur by chance 2.8 times in 100.

Group H, which rested 1 hour showed an average gain of 1.7, which was 18.1 less than Group A. The critical ratio is 2.03, indicating that a difference of this magnitude would occur by chance 5 times in 100.

Group I, with a 6-hour rest, lost, on

TABLE 4

Retention measured by changes over late rest intervals at trials 15–16

Rest Interval	Mean at Trial 15	Mean at Trial 16	Mean Change	σ_M
1 minute (A)	422.4	442.2	19.8 gain	5.6
10 minutes (G)	402.0	443.4	41.4 gain	7.9
1 hour (H)	397.2	398.9	1.7 gain	7.0
6 hours (I)	394.0	365.4	−28.6 loss	10.0
24 hours (J)	418.2	399.2	−19.0 loss	8.0
30 hours (K)	395.4	385.2	−10.2 loss	12.1

the average, 28.6 points, which is a difference of 48.4 between this group and Group A, yielding a critical ratio of 4.21.

Groups J and K lost 19 and 10.2 points respectively, yielding critical ratios of 3.96 and 2.26, when compared with Group A.

Comparisons of Group G with Groups H, I, J, and K yield critical ratios of 3.78 for G versus H; 5.51 for G versus I; 5.39 for G versus J; and 3.56 for G versus K. The only other critical ratios at trial 16 which approached significance were those in which the 1-hour rest group was compared with the 6-hour and 24-hour rest groups. The respective critical ratios are 2.48 and 1.95, both favoring the shorter rest period.

The conclusions to be drawn from this analysis of differential rest periods introduced late in learning are, first, that the longer rest periods of 6, 24, and 30 hours have significantly greater disturbing effects upon retention at trial 16 than do the shorter rest periods of 1 minute, 10 minutes, and 1 hour. The loss in skill at trial 16 seems to reach its maximum at the 6-hour rest interval. The losses at the 24- and 30-hour rest intervals are somewhat less than at the 6-hour interval, but not significantly so. In the second place, there is a tendency for the 10-minute group to gain more than the 1-minute rest group, suggesting a reminiscence effect similar to that appearing with the early rest groups.

GAINS BETWEEN TWO TRIALS FOLLOWING REST (TRIALS 6 AND 7 AND TRIALS 16 AND 17)

In order to study further the performances upon return from the rest interval an analysis of the data at the 7th and the 17th trials has been made. These are the second trials after rest, revealing such readjustment as may occur within the first trial. In Figure 9, the curve representing the changes in scores between trials 6 and 7 is presented, and in Figure 10, the curve showing the changes in scores between trials 16 and 17. Both

TABLE 5

Relearning measured by changes in scores at trials 6–7, following early rest

Rest Interval	Mean at Trial 6	Mean at Trial 7	Mean Change	σ_M
1 minute (A)	251.0	270.8	19.8	8.7
10 minutes (B)	300.4	327.0	26.6	6.7
1 hour (C)	274.1	320.7	46.6	5.7
6 hours (D)	286.3	344.5	58.2	6.5
24 hours (E)	281.5	330.8	49.3	5.9
30 hours (F)	282.8	323.4	40.6	6.5

TABLE 6

Relearning measured by changes in scores at trials 16–17, following late rest

Rest Interval	Mean at Trial 16	Mean at Trial 17	Mean Change	σ_M
1 minute (A)	442.2	455.0	12.8	5.9
10 minutes (G)	443.4	454.8	11.4	4.5
1 hour (H)	398.9	439.2	40.3	8.1
6 hours (I)	365.4	417.6	52.2	6.0
24 hours (J)	399.2	439.8	40.6	6.7
30 hours (K)	385.2	429.6	44.4	6.9

curves show a gain after the 1-minute rest, but the gain is larger for the groups with early rests. At the 10-minute rest interval, the groups which rested early continued to gain while the late-rest groups showed no gain. The 1-hour rest interval showed a substantial gain for both early and late rest groups, and this tendency is continued at the 6-hour interval, where both groups showed their largest gains. Following the 6-hour interval, the curves both show a drop at the 24-hour interval, and at the 30-hour interval they show practically the same gains.

In Table 5 the means at trial 6 and at trial 7 for Groups A through F, the mean changes, and their standard errors are given.

At the 7th trial Group A, the control group, gained 20 points; Group B, with a 10-minute rest, 27 points; Group C, with a 1-hour rest, 47 points; Group D, with a 6-hour rest, 58 points; Group E, with a 24-hour rest, 49 points, and Group F, with a 30-hour rest, 41 points.

The group comparisons yielding significant differences are Groups A versus C, A versus D, A versus E, B versus D, and B versus E. In general, the only group comparisons at trial 7 which showed significant differences are those between the shorter and the longer rest intervals. There is a fairly consistent tendency for increasing rests up to 6 hours to give increasing gains between trials 6 and 7, suggesting again the possibility of a warming-up effect taking

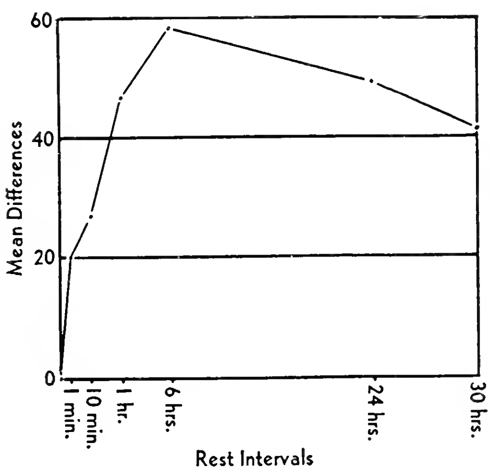

FIG. 9. Warming-up effect at trial 7.

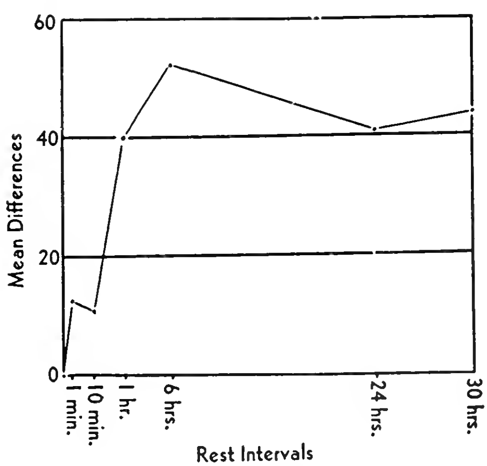

FIG. 10. Warming-up effect at trial 17.

place within the first trial of the task resumed after a longer rest.

In Table 6 the means at trials 16 and 17 for Groups A and G through K, the mean changes, and their standard errors are shown.

Group A gained 13 points; Group G, with a 10-minute rest, 11 points; Group H, with a 1-hour rest, 40 points; Group I, with a 6-hour rest, 52 points; Group J, with a 24-hour rest, 41 points; and Group K, with a 30-hour rest, 44 points.

The critical ratios indicate significant differences between A versus H, A versus I, A versus J, A versus K, G versus H, G versus I, G versus J, and G versus K. All these reliable differences at trial 17 are between the shorter and the longer rest intervals, there being no reliable differences among the longer rest intervals.

A comparison of the data in Tables 5 and 6 represented in Figures 9 and 10 shows that the retention curves are quite similar. Both early and late groups which rested 1 minute and 10 minutes gained significantly less than those which rested 1 hour, 6 hours, 24 hours, and 30 hours, and the differences between the three longer rest groups were, in both instances, insignificant. This similarity of the curves of the two groups suggests that there was a common factor operating both early and late different from primary and secondary growth. Such "growth" as was lost at trial 16, according to Snoddy's hypothesis, would merely be recovered at trial 17. But the data presented show that the relearning curves are clearly similar for both early and late groups. Hence a more logical explanation would be that the gains at the 7th and 17th trials are due to a common effect at trials 6 and 16, alike following early and late rests. This effect may provisionally be described as "warming-up." Further conjectures regarding the maximum at 6 hours will be considered later.

CHAPTER V

EFFECT OF SIZE OF SCORE

THE analysis of the data is continued in order to study what effect the size of scores had upon retention early and late in learning. The 11 groups of subjects were divided into low and high-score groups on the basis of their performance at trial 4 for those having early rest intervals and at trial 14 for those having late rest intervals. Trials 4 and 14 were selected as the basis for this division in order to counteract the effects of statistical regression. By making the division at these trials rather than at trials 5 and 15 it was possible to control to some extent the distortion which results from the tendency of the high and the low scores to regress toward their means (20). That is, the chance errors, making scores too high or too low on trials 4 and 14, will be cancelled out in the new measurements of trials 5 and 15.

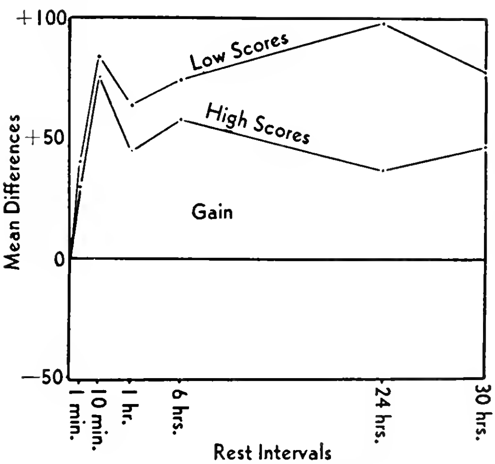

FIG. 11. Retention for low and high scores after rests at the 5th trial.

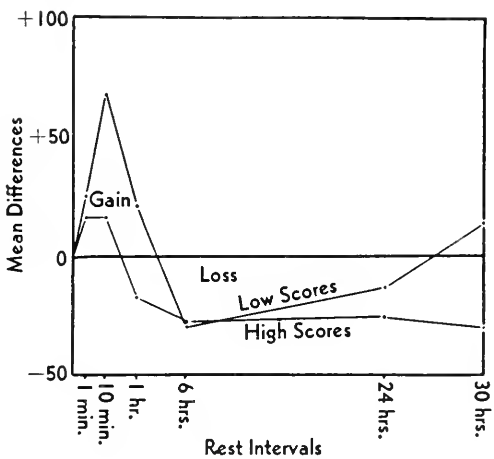

FIG. 12. Retention for low and high scores after rests at the 15th trial.

LOW AND HIGH SCORES AT TRIALS 6 AND 16, FOLLOWING REST INTERVALS

The curves representing retention for the low and the high-score groups at the 6th trial are presented in Figure 11, and the curves for the low and high-score groups at trial 16, in Figure 12. These curves are similar to those of the original groupings as shown in Figures 7 and 8, page 16.

At the 6th trial there is a rapid rise for both the low and the high-score groups at the 1-minute and 10-minute rest intervals, a drop for both at the 1-hour interval, and then a rise for both at the 6-hour interval. At the 24-hour interval the low-score group continues to gain while the high-score group shows a drop. They move closer together at the 30-hour interval, but with the low-score group still showing a gain considerably above that of the high-score group.

At trial 16, both the low and the high-score groups show a rise at the 1-minute rest interval, which is followed by a large gain for the low-score group but practically no gain for the high-score

TABLE 7

Comparison of low scores for retention over early rest interval at trials 5–6

Rest Interval	Mean at Trial 5	Mean at Trial 6	Mean Change	σ_M
1 minute	128.9	170.1	41.2	7.6
10 minutes	135.7	219.8	84.1	10.7
1 hour	130.2	194.9	64.7	10.2
6 hours	149.8	225.6	75.8	12.7
24 hours	141.9	239.4	97.5	8.8
30 hours	137.8	216.1	78.3	12.8
Average	137.8			

group at the 10-minute interval. At the 1-hour interval the low-score group still shows a gain while the high-score group shows a loss. At the 6-hour rest interval both show about the same loss. This loss is continued at the 24-hour interval, but to a less extent for the low-score group. At the 30-hour interval the low-score group makes a small gain while the high-score group continues to lose.

GAINS AT TRIAL 6 FOLLOWING EARLY REST

In Tables 7 and 8 the means at trials 5 and 6, the mean change over the rest interval, and the standard errors of the means are presented for the low and the high-score groups.

After the rest intervals at trial 5 the low and the high-score groups make gains as follows: Following the 1-minute rest, 41.2 for the low-score group and 30.9 for the high-score group; following the 10-minute rest, 84.1 for the low and 76.0 for the high; following the 1-hour rest, 64.7 for the low and 44.5 for the high; following the 6-hour rest, 75.8 for the low and 58.6 for the high; following the 24-hour rest, 97.5 for the low and 36.9 for the high; and following the 30-hour rest, 78.3 for the low and 47.1 for the high.

In general, the data are consistent in showing a greater gain for the low-score groups than for the high-score groups following rest intervals early in learning—the difference in gains being considerably larger following the longer rest intervals. This suggests that the lower scoring subjects were primarily responsible for the large gains following rests of long duration after the 5th trial, as presented in Figure 7, page 16. However, the consistency of gains following early rests is to be noted for both low and high scoring subjects.

TABLE 8

Comparison of high scores for retention over early rest interval at trials 5–6

Rest Interval	Mean at Trial 5	Mean at Trial 6	Mean Change	σ_M
1 minute	308.7	339.1	30.4	11.8
10 minutes	314.7	390.7	76.0	8.6
1 hour	305.2	349.7	44.5	12.0
6 hours	289.6	348.2	58.6	9.3
24 hours	289.3	326.2	36.9	13.2
30 hours	302.3	349.4	47.1	10.1
Average	301.1			

TABLE 9

Comparison of low scores for retention following late rest at trials 15–16

Rest Intervals	Mean at Trial 15	Mean at Trial 16	Mean Change	σ_M
1 minute	358.0	381.8	23.8	6.7
10 minutes	325.9	393.4	67.5	8.9
1 hour	328.0	348.8	20.8	10.9
6 hours	336.2	307.2	−29.0	16.7
24 hours	365.8	352.2	−13.6	13.2
30 hours	315.3	328.3	13.0	20.1
Average	337.8			

GAINS AND LOSSES AT TRIAL 16 AFTER LATE REST

In Tables 9 and 10 the means at trials 15 and 16, the mean change over the rest intervals and the standard errors of the means are given for the low and the high-score groups.

Following the 1-minute rest interval at trial 15, the low-score group gained 23.8 and the high-score group, 16.2. After the 10-minute rests, the low-score group showed a gain of 67.5, the high-score group, only 16.3. After the 1-hour rest the low-score group gained 20.8 and the high-score group lost 17.3. Following the 6-hour and the 24-hour rest intervals both groups lost—29.0 for the low and 26.8 for the high following the 6th interval, and 13.6 for the low and 26.2 for the high following the 24-hour interval. Following the 30-hour interval, the low-score group gained 13.0 and the high-score group lost 29.8.

Here, again, the low-score groups show greater gains or smaller losses than do the high-score groups, the greatest difference in scores occurring after the 10-minute and 30-hour intervals. This indicates that the low scores were primarily responsible for the gains following these rest intervals late in learning, as shown in Figure 8, page 16. However, loss is the rule at longer intervals for low as well as high scores late in practice.

HIGH SCORES AT TRIAL 6 FOLLOWING EARLY REST VERSUS LOW SCORES AT TRIAL 16 FOLLOWING LATE REST

Because the combined average at trial 5 for the high-score groups resting early in learning was approximately equal to the combined average at trial 15 of the low-score groups resting late in learning, as shown in Tables 8 and 9, it is apparent that a comparison of the performance of these two groups at trials 6 and

TABLE 10

Comparison of high scores for retention following late rest at trials 15–16

Rest Intervals	Mean at Trial 15	Mean at Trial 16	Mean Change	σ_M
1 minute	479.8	496.0	16.2	8.7
10 minutes	476.3	492.6	16.3	10.4
1 hour	465.2	447.9	−17.3	6.5
6 hours	445.5	418.7	−26.8	11.5
24 hours	465.9	439.7	−26.2	9.1
30 hours	466.0	436.2	−29.8	12.6
Average	466.6			

16 should show whether the size of the scores or the earliness or lateness of the rest intervals was responsible for the differences in gains over the various rest intervals.

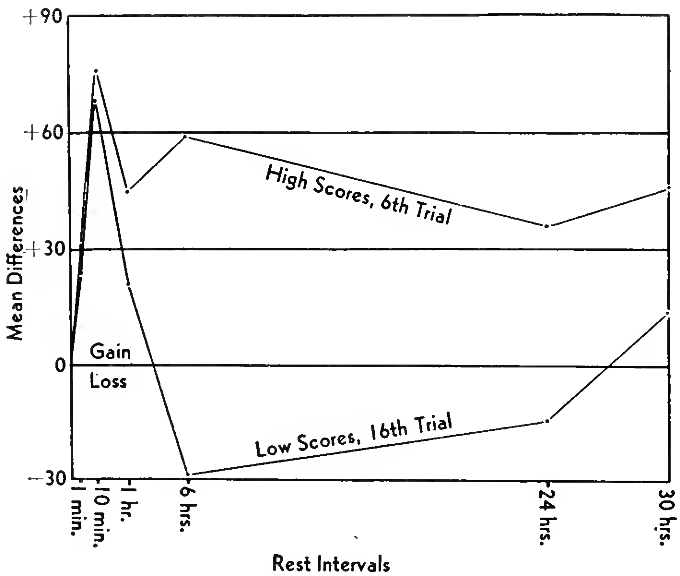

Fig. 13. Comparison of changes in scores for high score groups at trial 6, and for low score groups at trial 16.

In Figure 13, the retention scores of the high-score group at trial 6 and of the low-score group at trial 16 are compared.

Both the high-6th and the low-16th groups showed a rapid gain at the 1-minute and the 10-minute rest intervals. Both groups showed a drop over the 1-hour interval, but the drop was less for the high-6th group. Following the 6-hour rest the two groups are widely separated, the high-6th showing a gain and the low-16th, a loss. They continue to be separated after the 24-hour rest, with the high-6th showing a gain and the low-16th still showing a loss. At the 30-hour rest the low-16th group shows a gain, but it is still considerably below the level of the high-6th group.

In Table 11, the mean changes over

Table 11

Comparison of the retention scores for high scores at the 6th trial after early rests and low scores at the 16th trial after late rest

Rest Interval	Mean Change 6th Trial High Scores	Mean Change 16th Trial Low Scores	Differences	σ_D	t
1 minute	30.9	23.8	7.1	14.0	.51
10 minutes	76.0	67.5	8.5	12.8	.66
1 hour	44.5	20.8	23.7	16.6	1.43
6 hours	58.6	−29.0	87.6	18.9	*4.61*
24 hours	36.9	−13.6	50.5	19.3	2.62
30 hours	47.1	13.0	34.1	22.5	1.52

the rest periods, for the high-score group at the 6th trial and the low-score group at the 16th trial, their differences, the standard errors of the differences, and the critical ratios for the differences, are presented.

There were no significant differences between the high-6th and the low-16th groups over the 1-minute and 10-minute rest intervals, as shown by *t*'s (7) of .51 and .66 respectively. The small gains shown, however, were in favor of the high-6th group. (For groups of this size a *t* of 2.85 is necessary to reach accepted standards of significance, i.e., $p. < .01$.)

Over the 1-hour, 6-hour, 24-hour and 30-hour intervals the differences continue in favor of the high-6th group: 23.7, yielding a *t* of 1.43 at the 1-hour interval; 87.6 with a *t* of 4.61 at the 6-hour interval; 50.5 with a *t* of 2.62 at the 24-hour interval; and 34.1, with a *t* of 1.52 at the 30-hour interval.

These data indicate that there was a tendency for the high-score groups which rested after the 5th trial to make larger gains over the varying rest periods than the low-score groups which rested after the 15th trial, particularly over the longer rest periods. It appears, then, that the determining factor in these differences was the earliness or lateness of the rests rather than the level of the scores at the time the rests were interpolated.

Chapter VI

Interpretation

THE SNODDY HYPOTHESIS

This investigation has sought to test experimentally the Snoddy hypothesis, the principal tenet of which is that learning progress is determined by two sets of factors: primary and secondary growth. In his own study, Snoddy used the mirror drawing apparatus, but it is evident from his reply to Doré and Hilgard (26) that he approves the Koerth pursuit rotor used in this experiment as a satisfactory test of primary and secondary growth and one which yields results comparable to the mirror drawing apparatus. Furthermore, he has cited Humphreys' (12) experiment, in which the pursuit rotor was used, as giving evidence supporting his hypothesis.

EVIDENCE BEARING ON PRIMARY GROWTH

According to Snoddy (28), primary growth is characterized by its earliness, its stability, and its dependence upon interpolated time. In his own words:

> . . . Primary growth is a positive function of the length of the interpolated time interval. (p. 20).
>
> Primary growth is early and stable . . . , and because it is an increase in stability, it must be continuous. (p. 35).
>
> Primary growth is a continuous growing function which can never decrease. (p. 36).

From these statements, it is clear that an experimental test of primary growth must take into consideration its threefold characteristics: earliness, continuity, and stability.

1. *Earliness.* The rest periods for five of the groups in this study were placed early in learning—after the 5th trial in a series of 20. These rest intervals early in learning resulted in larger gains than rest intervals of the same duration interpolated late in learning. And the analysis of high scores at the 6th trial and low scores at the 16th trials, Figure 12, page 21, showed that earliness and lateness of rest intervals, and not the size of the score, were responsible for the differences in gains. This indicates that the gains which would be predicted agree with Snoddy's view that primary growth occurs early in learning.

2. A second characteristic of primary growth is that it is a *continuous* ever-growing function. At this point the data of the present study do not support Snoddy. It can be seen by reference to Figure 7, page 16, that the extent of gains at the 6th trial are not proportional to the amounts of time interpolated following the 5th trial. In fact, the 10-minute rest period produced a larger gain than the 6, 24, or 30-hour rest periods.

Rather, the above finding is in harmony with the study of Travis (31) with the pursuit oscillator, in which he found that a rest period of 20 minutes was significantly more effective than rest periods of 5 minutes, 48 hours, 72 hours and 120 hours, that the 5-minute rest period was more effective than the three longest rest periods, and that there was little difference among the longest periods.

3. *Stability.* Snoddy has used the cumulative arithmetic mean as a measure of the stability of primary growth. Concerning this measure he writes:

> The cumulative mean is indeed a satisfactory

measure of the stability factor, since no averages for days or circuits ever go below it. But it will be recognized that this cumulative mean is much more than a stable measure; it is indeed a measure of a *growth process which increases,* so far as we can see at present, without limit (28, p. 40).

In the present study, this measure was used with Group I, which rested 6 hours after the 15th trial, to test the stability of primary growth. Group I was used because it showed the greatest loss of any of the groups resting late in learning. In Figure 14, the averages for this group of trials 1-20 are shown by the solid line and the cumulative means of trials 1-15, by the broken line. It is apparent that the drop at trial 16 after the 6-hour rest is still considerably above the cumulative mean at trial 15, which indicates that in terms of Snoddy's measure of stability the data at this point support his claim for the stability of primary growth.

Doré and Hilgard (5) have challenged Snoddy's use of the cumulative mean as a measure of primary growth, showing that he failed to note that the cumulative mean of a logarithmic curve bears a definite relation to that curve—that the cumulative mean of the points in a logarithmic curve (when plotted as a straight line) is another curve of one-half of the slope. They point out that if primary growth is expressed as the cumulative mean and secondary growth found by subtracting primary growth from total growth secondary growth then becomes equal to primary growth minus a constant representing the initial score. This would mean that the primary and secondary growth differentials are equal after the first score, which would deny Snoddy's statement that early and late massing of practice have different effects because of early preponderance of primary growth and later preponderance of secondary growth. These objections may make less important the stability of learning in our data as determined by Snoddy's method.

So far, it is apparent that the present data support Snoddy's contention that primary growth occurs early in learning and that it is stable when measured by the cumulative mean, but they do not

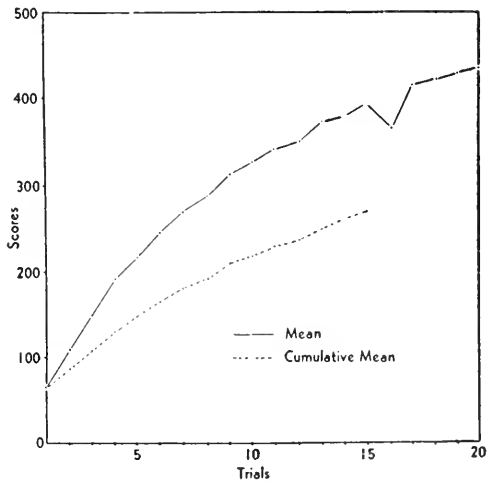

FIG. 14. Comparison of the arithmetic mean and the cumulative arithmetic mean for Group I with a 6-hour rest.

agree with his claim that it is a continuous, ever-growing function. They neither confirm nor refute his use of the cumulative arithmetic mean as a measure of primary growth.

EVIDENCE BEARING ON SECONDARY GROWTH

In his more detailed discussion Snoddy (28) states that secondary growth occurs late in learning, that it is unstable and readily lost over long-time intervals, that it rests on a base of primary growth, and that it is the difference between total growth and primary growth. To quote him directly:

> Secondary growth has two important attributes, namely it comes late and is unstable, that is, it meets with heavy losses as it faces the long time intervals. (p. 46).

> Secondary growth at any point can be found by subtracting out the primary growth at that point. . . . However, when we perform this simple operation of subtracting the two scores, we should be clear as to what is involved in the procedure. The two growths are completely opposed . . . and when we subtract out . . . primary growth we are actually considering this score as zero of secondary growth. Secondary growth then is being measured from a base, which under constant conditions, is constantly rising. (p. 79).
> The late growth has no base of its own, but given a base that has been built up by stimulation and interpolated time, the increment is greater as the interpolated time is removed. (p. 93).

The differential rest periods for five groups in the present study were interpolated late in learning—after the 15th trial in a series of 20. These groups resting late in learning showed a loss in score for the longer rest intervals, as compared with gains following identical rest intervals early in learning. This is shown in Figures 7 and 8, page 16.

The most pronounced instance of this instability following rests late in learning is over the 6-hour rest interval, as shown in Tables 3 and 4, pages 17 and 18. This interval produced an average gain of 66.2 when interpolated following the 5th trial, and an average loss of 28.6 when placed after the 15th trial, or a difference between the means of 94.8 in favor of the early rests. This agrees with Snoddy's characterization of secondary growth as being unstable.

However, the data do not agree with Snoddy's claim that secondary growth is greater as interpolated time is removed. Evidence of this is shown in the fact that the groups which rested 24 and 30 hours after the 15th trial showed less loss than the group which rested 6 hours.

When primary growth is measured by the cumulative arithmetic mean the present data support Snoddy's claim that secondary growth rests on a base of primary growth. This is shown in the test of the stability of primary growth of Group I by means of the cumulative mean. As shown in Figure 14, Group I had built up a considerable base of primary growth, as measured by the cumulative mean, at the 15th trial. There is a difference here between primary growth and the total growth of 126 points, which, according to Snoddy, would represent secondary growth.

However, over the 6-hour rest interval following the 15th trial only 29 points of secondary growth were lost. In other words, secondary growth lost 29 points out of a total of 126 following a 6-hour rest interval late in learning. This would indicate that either the rest period was not long enough for the unstable character of secondary growth to manifest itself or that the cumulative mean was not a satisfactory measure of primary growth for Group I. The latter seems to be the more likely since there was less loss over the 24-hour and the 30-hour intervals than over the 6-hour interval.

It appears, then, that the present findings support Snoddy's contention that something (similar to what he calls secondary growth) occurs late in learning and that it is unstable and hence lost over long intervals of time. They are at variance with his theory that the loss over long intervals is proportional to the amount of interpolated time, and they further question his use of the cumulative mean as a measure of primary growth.

ADDITIONAL FACTORS OF THE PRESENT DATA

From the foregoing discussion of the present test of the Snoddy hypothesis it is apparent that primary and secondary growth—or early and late learning factors—do not adequately account for all the findings of this study. One such factor is the presence of an inhibiting or interference tendency early in learning.

The nature of the pursuit task is such as to produce a large amount of interference at the beginning of learning, as the disc turns at the constant speed of one revolution per second. This makes it necessary for the subject to adapt himself quickly to the apparatus, and does not give him opportunity to adjust the task to his own rate of movement. Interference was obviously greater and continued for a larger number of trials with the subjects with poor eye-hand coordination than with the subjects with good eye-hand coordination.

The subject showed little evidence of strain as he held the stylus before the start signal was given. (The task appeared so simple.) But when the start signal was given and he made a stabbing movement at the target, only to have it elude him, he ceased to be relaxed and strain became apparent. Finding it difficult to make contact he began to bend the wrist, holding the stylus at nearer a right angle, rather than horizontal to the disc. When the wrist was bent to the point where the handle of the stylus struck the revolving disc, the shock of striking the disc caused him to relax for a moment and the pursuit movements then became more accurate. As learning progressed these interfering movements gradually disappeared.

From the present study it is not possible to provide experimental verification of this conception of interference and hence it is presented as an hypothesis which needs to be verified by further research. However, one approach to the data of the present study which appears to be coherent with this hypothesis is the change in relative variability from trial 1 through trial 20. In Figure 15 a comparison is made of both absolute and relative variability for Groups B through K combined into a single group of 417 subjects. Absolute variability

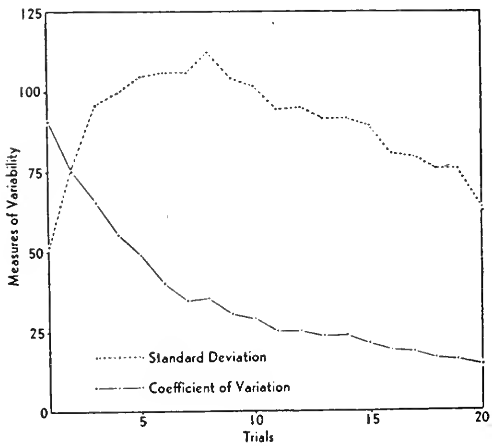

FIG. 15. Absolute and relative variability for Groups B through K combined.

shows a rapid increase from trials 1 to 8 and a steady decrease from trials 9 through 20. Relative variability shows a rapid decrease from trials 1 to 7 and a somewhat slower decrease from trials 8 through 20. This latter curve is consistent with the hypothesis of interference presented above since relative variability is at a maximum early in learning and gradually decreases as learning progresses.

The presence of an interference factor has been noted in other investigations.

SNODDY'S CONCEPT OF INTERFERENCE

In seeking to interpret the data for his experiment on mirror drawing coordination in terms of only two determining factors—primary and secondary growth—Snoddy came up against results which were not consistent with such an interpretation. He found that for the group which had continuous practice the logarithmic curve fitted to the data by the method of least squares failed to pass through the first few points, and in explaining this Snoddy drew the conclusion that "either the log equation is a misfit entirely or the two growths under conditions of continuous practice have an interference effect upon each other. . . . It seems possible that this interference effect—which is gradually overcome—in the early part of continuous practice, is the sole cause of the poor fit of the logarithmic equation at the early stations." (28, p. 29).

Since Snoddy believed that this failure of the equation to pass through the early stations of the continuous practice group, which naturally would have a low primary growth base, was evidence of an interference factor, he decided to test this assumption experimentally by an arrangement which would allow a large primary growth base before the secondary growth would appear. He therefore arranged for practice on the mirror drawing apparatus which should be preceded by a rest period and followed immediately by practice not preceded by a rest period. He says of this arrangement:

> The growth in circuits preceded by the time-interval will be accelerated by the time interval; but when we come to the pairs, which have no interval between them, we should have primary growth in the first circuit and secondary growth in the second, since continuity is a determiner of secondary growth. . . . The condition would therefore seem to be ideal for determining an interference effect, that is, a loss in the second member of each pair. (28, p. 32).

The results of this study are reproduced in Figure 16, where the encircled stations represent mean velocity scores which were preceded by a 2-minute time interval, except a and b, which were preceded by 24-hour intervals. The boxed stations represent the mean velocity scores which followed immediately after the encircled stations—that is, they were not preceded by a rest interval.

It is clear that an interfering or inhibiting effect is present in the trials which were not preceded by a rest interval, as the velocity scores represented by boxed stations are, with the exception of one, below that of the rest interval stations. However, this denies Snoddy's tenet that secondary growth is facilitated by the reduction of time, as the losses are not smaller late in learning for the continuous practice trials. In fact, his data show an advantage for spaced practice throughout the series of trials.

It is apparent also that the interference effect was present in the early as well as in the late stages of learning, which contradicts Snoddy's statement that primary growth is prominent in the early stages and secondary growth in the late stages of learning.

Since Snoddy's definition of interference is non-operational in his own experiment it is impossible to use it to account for the results of the present experiment. In adding an interference factor, however, we are recognizing aspects of his data as well as of ours.

OTHER CONCEPTIONS OF INTERFERENCE

In one of his earlier studies (1920), Snoddy (27) employed a concept of interference which he defines somewhat more clearly but which he discarded in his more recent studies. He called it the "irradiation picture" and described it as follows:

> In the early tracings in Stage I, the subject grasps the stylus, much as he would a pen or pencil—the functioning of the musculature concerned being characterized by a certain ease and facility; but, as the recess period

is continued, the subject grasps the stylus with an observable stiffness; the staff of the stylus, which at first lay back in the hand, is now perpendicular to the plane of the apparatus; the arm, which was at first mobile, now becomes stiff and rigid; the upper trunk, which at first was inclined over the apparatus, now becomes stiff and erect; the opposed musculature in the legs becomes tensed, resulting in a marked rigidity and stiffness; apparently the last musculature to be added to this assimilation is that of the unused arm. (pp. 51-52).

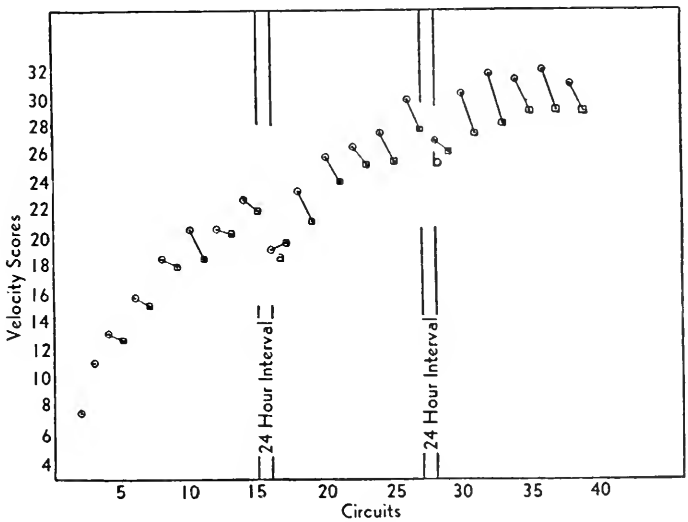

Fig. 16. Interference between the growth processes. (Reproduced from "Snoddy.")

Woodworth (35) says "if practicing one act makes another act more difficult to perform we speak of interference." He speaks of "associative interference" as having to do with the learning of an act, and "reproductive interference" as referring to the execution of an act already learned.

Book (2), 1908, in his classic study on typewriting used a concept of interference to explain the growth he found in the retention of typewriting skill after rest. He attributes this growth to the disappearance with the lapse of time of numerous psycho-physical difficulties, interfering associations, poor habits of attention, incidentally acquired in the course of learning, which, as they fade, leave the more firmly established typewriting associations free to act.

In Ward's (32) recent study, 1937, on reminiscence in rote learning he employs the idea of interference similar to that of Book. He writes:

. . . the explanation of reminiscence in terms of the dying out of a positive interfering tendency growing up during learning is a good one. It is pretty well agreed that what we call "inhibitions" in the conceptual sense, without implying anything as to their nature other than a tendency away from the reactions under consideration are set up during the course of learning.
Speaking in everyday terms, there is an interaction of attempts not to make incorrect responses and attempts to respond correctly. Often certain new and incorrect responses are partially learned also. It seems natural in the same everyday terms to expect that a short rest from the activity involved should allow one to "forget" these mistakes which are not as well learned as the correct responses, with which they have partially interfered. In terms of such concepts as those of

associative and retroactive and proactive inhibition, the interval of rest allows the dying out of these inhibitions which are assumed to have a more rapid rate of disintegration than do some of the positive excitatory tendencies found at the same time. (pp. 102-103).

Newman (21) in his study of the effect of "crowding" on forgetting states that spacing in time allows interference to disappear during the learning process. He emphasizes also that crowding the material on to the subject tends to increase the amount of interference.

McGeoch (18), 1939, has summarized the various hypotheses for interference in this manner:

At the present the best hypothesis is that the interferences among the parts of the material since they are less strong than the correct associations, drop out faster, disinhibiting the correct associations. This explanation unifies the data for the distribution of practice and for reminiscence in that it offers a common basis for the two. (p. 339).

WARMING-UP EFFECT

Another finding of the present study not accounted for by the Snoddy hypothesis of primary and secondary growth is the presence of a "warming-up" factor. Following the longer rest intervals both early and late in learning, the subject made several preliminary adjustive movements as he resumed his task, such as changing stance, changing his grip of the stylus, and changing the position of the hand not being used. It seemed necessary, too, for him to become oriented again to the experimental situation—that is, the room in which the test was given, the apparatus, and the experimenter—and to his own level of aspiration.

As was mentioned in Chapter IV, evidence provisionally designated as warming-up was shown in Figures 9 and 10, page 19. The curve in Figure 9 for retention scores at trial 7 is very similar to the curve in Figure 10 for retention scores at trial 17. In other words, retention scores at trials 7 and 17 show the operation of a warming-up factor common to both. This factor obviously is not accounted for by either primary or secondary growth since by hypothesis they are opposite in effect. Furthermore, it differs from interference in that its magnitude was the same both early and late in practice, while interference was great early in practice and gradually eliminated late in practice. It appears, then, that warming-up is a function of time which differs from primary and secondary growth and interference.

Previous studies have noted and discussed warming-up. Thorndike (29) in 1903 defined warming-up as "that part of an increase of efficiency during the first 20 minutes (or some other assigned early portion) of a work period, which is abolished by a moderate rest, say of 60 minutes. Such warming-up should show itself clearly in individuals at or near the limit of practice, and, in others, should compound with the effects of practice to make the rise in efficiency especially rapid in the first 20 minutes of work." (p. 66).

Robinson (23) has defined warming-up as a "rise in efficiency which is steeper and more temporary than the rise in successive daily performances." (p. 622).

In a study on tapping, Wells (33) shows actual evidence of the effect of warming-up. He found there was warming-up improvement when 30-second tapping tests were separated by 2½-minute rests, but in six successive 5-second periods within each 30-second period of continuous tapping the usual decrement appeared.

Robinson and Heron (24) found evidence of warming-up in their study on reciting the alphabet backwards. In explaining the action of warming-up Robinson (23) concludes that "we are dealing with short-lived habits, formed during the experimental sittings and lost before the next sittings. These might consist largely of a mental attitude, or they might involve also the attainment of a favorable muscular posture."

In the present study the term warming-up is used to describe the very rapid reinstatement of a previously reached score after a first trial in which the task is resumed. It distinguishes the second trial after rest from the first trial after rest and is a different function of time. It may be that this factor is rapid relearning, but its appearance in the second trial following rest strongly suggests warming-up.

THEORY OF TIME FACTOR IN ROTOR LEARNING

Having considered the findings of the present study which require explanation, namely, gains early in learning, losses late in learning, interference, and warming-up, a tentative theory of changes over rest may be advanced to account for the results obtained. The general course of improvement is accepted as given, although, of course, a complete theory of pursuit learning would have to account for it also.

On the pursuit rotor, interference and warming-up may be inferred to operate throughout the course of learning with different effects at different stages. Interference is assumed to be greatest in the first few trials and to become less as learning progresses, while warming-up is inferred to increase rapidly during the first few trials but then to remain fairly constant throughout the rest of the learning. Rest intervals tend to remove interference but necessitate warming-up for subsequent trials. Large gains occur over rest intervals early in learning because the amount of interference removed is greater than the warming-up needed to establish preceding levels of scoring. Toward the end of learning losses occur over rest periods because the warming-up required becomes greater than the amount of interference removed. This counter-action of interference and warming-up gives rise to the conception of "true learning," i.e., the inferred score when obtained learning is corrected for interference and warming-up.

PRESENT THEORY AND SNODDY'S HYPOTHESIS

The large gains over early rest intervals, which Snoddy attributed to primary growth, are explained in the present theory as being the result of the elimination of interference during the rest intervals. The advantage of spaced practice according to the theory is not that it provides opportunity for primary growth over the rest periods but rather that it tends to eliminate ineffectual responses which were interfering with the development of effective responses. This view of the advantage of spaced over massed practice has also been suggested by McGeoch (18), Ward (32), and Newman (21), and was discussed earlier.

Snoddy's concept of secondary growth is not necessary to explain losses over rest periods late in learning if the present theory is acceptable, since it accounts for them adequately by assuming that interference has been reduced to the point where warming-up is greater than interference. The losses revealed in the first trial after rests were quickly recovered in the second trial, indicating clearly that prior learning was not really lost, but could be quickly restored after brief warming-up.

The theory also avoids the ambiguity of Snoddy's conception of interference as an antagonistic interaction between primary and secondary growth. All the factors in learning, according to our theory, are present throughout the entire course of learning, differing only in the degree to which each is effecting learning at any given stage.

It is not to be understood that the conjectures represented in the foregoing discussion are in any sense a final or complete theory of what is happening during the acquisition of the pursuit skill, or over the interpolated rest periods. The conjectures are offered rather as alternatives to Snoddy, showing how data consonant with his hypothesis are also consonant with alternative hypotheses. While the alternatives presented have some advantages over Snoddy's hypothesis, the underlying processes of "true learning," "interference," and "warming-up," have yet to be substantiated through supporting experiments.

PERMANENCE OF CHANGES OVER REST INTERVALS

The final scores for groups resting early in learning, as compared to groups resting late in learning (Table 2, page 14), present some difficulties for Snoddy's theory, since the end amounts of growth should differ under the two conditions of rest. This comparison showed that the groups which rested early in learning made significantly larger gains over rest than those which rested late. However, when the final scores at trial 20 were compared, they had both reached about the same score level. Obviously, the large gains of the early rest groups were not maintained, and the losses of the late rest groups were quickly overcome. As has been pointed out, these large gains following rest intervals early in learning are attributed to the reduction of interference and the losses following rest intervals late in learning are due to warming-up. Hence the equal scores at trial 20 are exactly what the proposed theory would demand, since by 5 trials after a rest, warming-up and interference are alike for both early and late resting groups, and the baseline of 20 trials of "true learning" is common to both.

The comparison of the score changes following rest periods with the final scores tends to question an assumption by Hull and others (11) in their recent mathematical analysis of rote learning. They state that the effectiveness of a rest interval in distributed practice is solely a function of the increase in score over this interval. (p. 124). Our data show, however, that the changes over the rest intervals may have had little to do with the end results since they were so readily modified by the trials which immediately followed. In Figure 3, page 10, for example, it can be seen that Group B, after a rest of ten minutes at the 5th trial, made a large gain at trial 6. However this gain was not maintained at trial 20 since the score for Group B is below that of Group A and Group C, both of which showed smaller gains at trial 6 than Group B.

Our theory as presented does not make specific allowance for relearning after rest, since it is based on the conception of no true forgetting over these short intervals. Hence the fact of final scores essentially alike is confirmatory. Since all final scores were not alike, a more precise formulation would require consideration of further factors involved in relearning after rest.

PRESENT THEORY AND REMINISCENCE

This theory is entirely in harmony with the theories of reminiscence by McGeoch (18), and by Ward (32). They have emphasized the removal of inhibiting or interfering factors during rest as the primary determinant in the gains which followed. The results of the present study for the 10-minute rest groups both early and late in learning, as shown in Figures 7 and 8, page 16, indicate that a rest of 10 minutes produced larger gains than a 1-minute rest. Since our data show a drop at the 1-hour rests both early and late, it is assumed that the point of optimum reminiscence lies somewhere between 1 minute and 1 hour. From the present data it is not possible to determine the length of the rest which gives the greatest reminiscence effect. The study by Travis (31) showed that 20-minute rests were better than 5-minute ones in pursuit learning.

LIMITATIONS OF THE PRESENT THEORY

The present theory as outlined is limited since it has not accounted for the specific differences at each rest interval. It is limited, too, by the fact that there may be a genuine "forgetting" factor present in the losses over the longer rests which has not been accounted for. Furthermore, it may be shown that the gains over the longer rest periods found in our study and in those by Buxton (3), by Ballard (1), and by Newman (21) are not adequately explained. That is, interference should be recovered from relatively quickly. Yet gains over very long intervals are reported. It is conceivable that there may be also some sort of maturational process not considered in our theory. These omissions do not negate the cogency of the specific factors inferred in the proposed theory, but they suggest possible elaborations.

SUMMARY

Significantly large gains in score occured when rest intervals were interpolated early in learning, which is in agreement with Snoddy's concept of primary growth. The data show no agreement with his claim that primary growth is a continuous function of time. Results support Snoddy's contention that something (similar to what he calls secondary growth) occurs late in learning and that it is unstable and hence lost over long periods of time, but the loss over long intervals is not found to be proportional to the amount of interpolated time. Furthermore, there is evidence for interference and warming-up factors not adequately treated by Snoddy.

Snoddy's conception of interference as opposition between primary and secondary growth was rejected because his data tended to refute his description of it. Instead, the concept of interference as inhibition or conflict between incorrect and correct responses in the early stages of learning, as described by Book, Ward, McGeoch and others, was adopted. The presence of a warming-up factor as adopted has been shown in the studies of Wells and of Robinson and Heron.

A tentative theory was formulated to explain the changes over rest periods in pursuit learning. It holds that interference and warming-up operate throughout the course of learning, but with different effects at different stages. Interference is greatest at the beginning and gradually diminishes as learning progresses, while warming-up increases rapidly during the first few trials and then remains fairly constant throughout the rest of learning. Rest intervals tend to remove interference but necessitate warming-up for subsequent trials. Large gains occur over rest intervals early in learning because the amount of interference removed is greater than the warming-up effect. Losses occur over rest intervals late in learning because warming-up becomes greater than the amount of interference removed. "True learning", then, is obtained learning plus

the difference between interference and warming-up.

This theory accounts for the large gains early and the losses late in learning without employing Snoddy's conception of primary and secondary growth. Furthermore, it avoids the ambiguity of assuming, as Snoddy does, an antagonistic relationship between earliness and lateness in learning. It is in harmony with the theories of reminiscence of Ward and McGeoch.

The theory is limited in that it does not give a complete picture of the retention curve, that it does not include a "forgetting" factor, which may actually be present, and that it may not account adequately for a change in growth which may occur over the longer rest periods. Elaboration of the theory along these lines is possible without rejecting the proposals as stated. Such further approximations to a more complete theory of pursuit learning must wait upon the accumulation of additional data.

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